The Eightfold Way, Quarks

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Strangeness

Interaction of pions with nucleons produce particles which have unusual production and decay properties, such as the K, Λ, and Σ.

- Produced in pairs:

$$\pi^- + p \to K^0 + \Lambda^0 \text{ but}$$
$$\pi^- + p \to K^0 + n \text{ never occurs}$$

  even though no other conservation law would be violated by the second reaction.

- Produced via strong interaction,but don't decay into particles that decay rapidly via the strong interaction.

Conservation of Strangeness

These odd properties can be organized by proposing a new quantum number S, **strangeness**.

The production in pairs is explained by the two product particles having $S = +1$ and $S = -1$, with nonstrange particles assigned $S = 0$.

The slow decays are explained by assuming that strong and EM reactions obey conservations of S, but the weak interaction does not. Decay violates strangeness conservation and proceeds slowly via weak interaction.

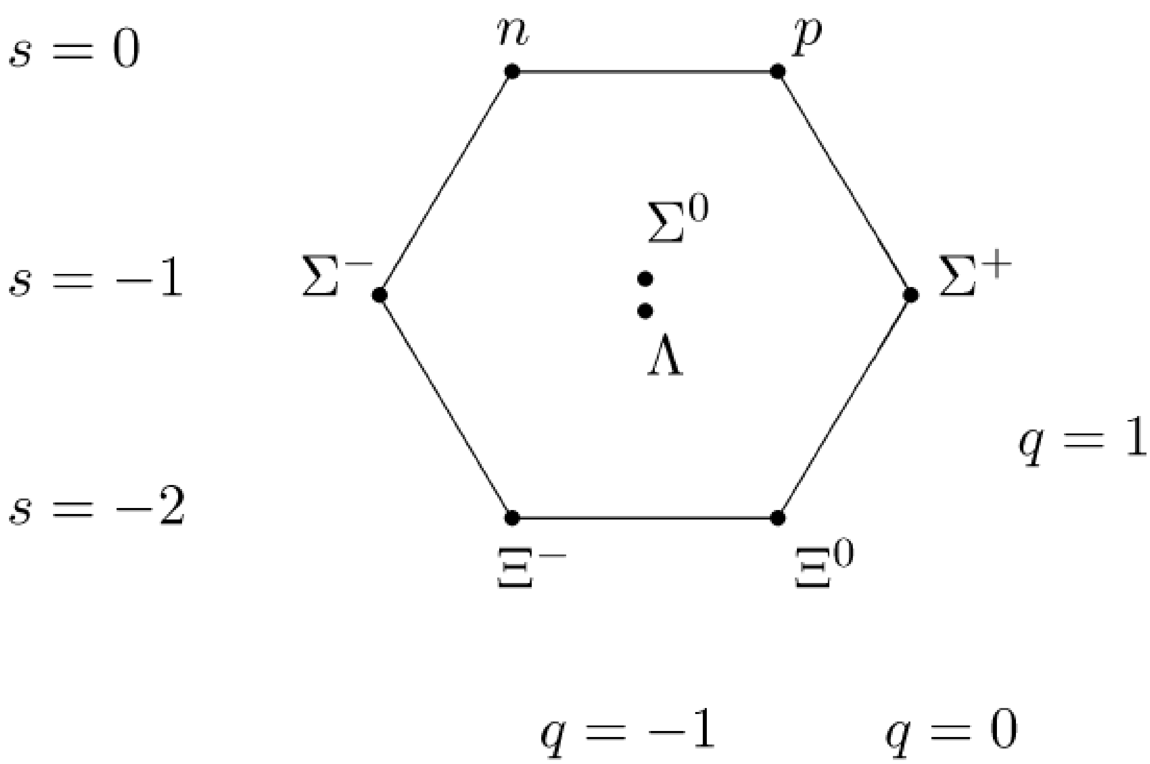
The eightfold way

When there were several hundred particles, how to organize them?

In 1961 Gell-Mann and Ne'eman plotted charge vs. strangeness in a hexagonal pattern for several groups of particles, and for the spin-$\frac{3}{2}$ baryons, there was a gap in the pattern. Gell-Mann used this to predict the properties of the missing particle, and the Ω^- was detected with the expected properties in 1964.

This is very similar to what Mendeleyev did with the chemical elements a century before.

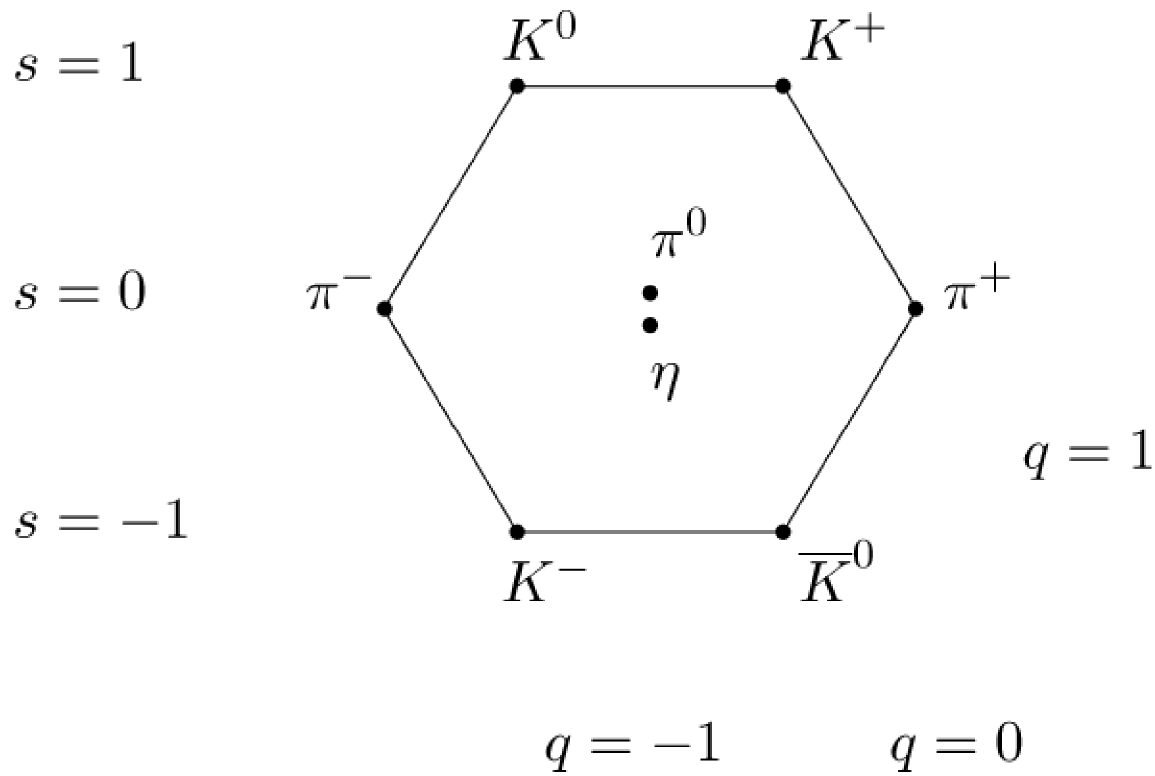
The baryon octet



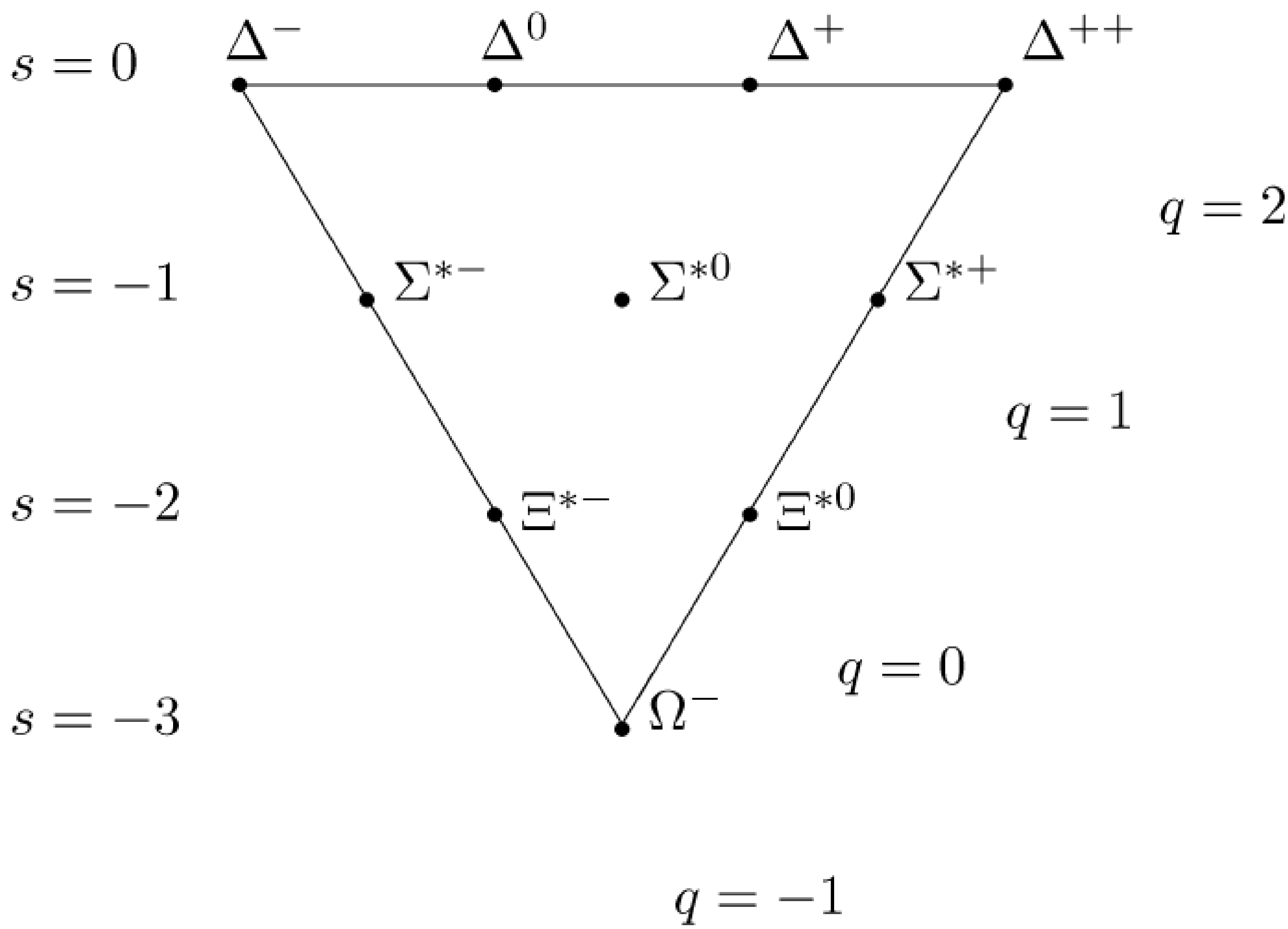
Pictures from

`http://en.wikipedia.org/w/index.php?title=Eightfold_way_%28physics%29&oldid=47142186`

The meson octet



The baryon decuplet



The Ω^- was not known when this pattern was discovered.

Quarks

Gell-Mann and Zweig proposed that hadrons are made of substructures known as **quarks.** Originally three proposed: **up, down** and **strange.** Later evidence indicates three more **top, botton** and **charm.**

- Quarks have fractional charges of $+\frac{2}{3}e, -\frac{1}{3}e$

- Mesons: quark and antiquark: $q\bar{q}$, bound by gluons.

- Baryons: qqq bound by gluons. The proton is uud, neutron udd.

- Antibaryons: $\bar{q}\bar{q}\bar{q}$, made of antiquarks.

See table 15.4 for the "quark chemistry" of various particles.

Quark confinement

No isolated quark has ever been observed. They seem to be confined by the strong “color” force which *increases* with separation distance.

Before sufficient (infinite?) energy can be applied to separate quarks, this energy makes virtual quarks from the vacuum real, which bind with the “splitting” quarks, so real, separated quarks never appear.